Contemporary operative caries management: consensus recommendations on minimally invasive caries removal.

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Abstract

The International Caries Consensus Collaboration (ICCC) presented recommendations on terminology and on carious tissue removal and managing cavitated carious lesions. It identified dental caries as the name of the disease which dentists should manage and control activity of existing cavitated lesions to preserve hard tissues, maintain pulp sensibility and retain functional teeth long-term. The ICCC recommended the level of hardness (soft, leathery, firm, and hard dentine) as the criterion for determining the clinical consequences of the disease and defined new strategies for carious tissue removal: 1) *selective removal of carious tissue*—including *selective removal to soft dentine* and *selective removal to firm dentine*; 2) *stepwise removal*—including stage 1, *selective removal to soft dentine*, and stage 2, *selective removal to firm dentine* 6 to 12 months later; and 3) *non-selective removal to hard dentine*—formerly known as *complete caries removal* (a traditional approach no longer recommended). Adoption of these terms will facilitate improved understanding and communication among researchers, within dental educators and the wider clinical dentistry community. Controlling the disease in cavitated carious lesions should be attempted using methods which are aimed at biofilm removal or control first. Only when cavitated carious dentine lesions either are non-cleansable or can no longer be sealed, are restorative interventions indicated. Carious tissue is removed purely to create conditions for long-lasting restorations. Bacterially contaminated or demineralizsed tissues close to the pulp do not need to be removed. The evidence and, therefore, these recommendations support minimally invasive carious lesion management, delaying entry to, and slowing down, the destructive restorative cycle by preserving tooth tissue, maintaining pulp sensibility and retaining the functional tooth-restoration complex long-term.

Introduction

The prevalence of dental caries has decreased in many countries over the last three decades. Despite this significant achievement, dental caries, a preventable disease, still remains the most prevalent worldwide, affecting billions of people and generating significant global healthcare costs [1,2]. Therefore, how the oral healthcare profession manages dental caries has become the central theme in reducing its burden globally. Strategies to achieve this must be evidence-based and/or informed. Recommendations are becoming supported by evidence synthesised from clinical studies [3]. However, this is complicated by the use of different terms describing more or less the same management strategies. Researchers and clinicians are not speaking the same professional language. Another complicating factor is the gap between research findings and their implementation into clinical practice. The reasons for this difference are complex but there are a number of likely contributing factors such as inconsistencies in clinical guidelines among professional groups, differences in dental education, which relies often on out-dated concepts, national healthcare policies and remuneration systems [4]. These issues need to be tackled if the oral healthcare profession is to be seen worldwide as a responsibility-taking health promoting organisation.

An initial step in achieving these changes was the establishment of the International Caries Consensus Collaboration (ICCC); 21 international clinical experts in cariology, operative dentistry, biomaterials science, clinical trials, systematic reviews and guideline development from 12 countries met in Belgium in February 2015, to develop expert consensus for recommendations on dental caries related terminology and for dealing with carious tooth tissue removal and managing cavitated carious lesions [5,6,7].

Why are such recommendations necessary?

For the oral healthcare practitioner who treats patients on a daily basis, dental caries and its sequelae makes up the bulk of their workload. The traditional management approach has been to remove all carious tissue, in the erroneous belief that this will stop the caries process, and restore the resulting cavity with a dental restorative material. Over the last 30 years however, better understanding of the caries process and clinical trial evidence on carious tissue removal methods have supported contemporary alternatives to this outdated “drill and fill” protocol. The clinical circumstances around when to use which method are daunting and somewhat confusing, with information dispersed throughout an ever expansive literature. In addition, the same methods are explained using different terminology in different countries. This paper, therefore, discusses what the alternative terms for the methods mean and when to do what in the operative management of the cavitated carious lesion which has not responded to non-operative prevention regimes in the first instance. This paper deals with teeth with cavitated caries lesions where the pulp is diagnosed as vital (positive sensibility test) or reversibly inflamed.

What is dental caries?

Dental caries is the disease that results from an ecologic shift in the bacteria within the dental plaque biofilm. An initially balanced population of commensal micro-organisms in a healthy plaque biofilm alters as an increasingly favourable environment for aciduric and acidogenic microflora develops within the stagnating biofilm, after stimulation by frequent consumption of fermentable dietary carbohydrates. The resulting shift in biofilm activity brings about an imbalance in de- and re-mineralisation, leading to net mineral loss within dental hard tissues; the earliest sign and symptom is the carious lesion [8]. Dental caries is not an infectious disease, which needs be “cured” by removing bacteria. Instead, it can be managed behaviourally by controlling its causative factors, i.e. the supply of fermentable carbohydrates and the presence and maturation of the bacterially-populated dental biofilms. If, however, such patient behaviour change is not initiated by the practitioner along with their oral healthcare team, or the responsibility taken by the patient to adhere to such preventive advice, and thus the lesion activity is not controlled, the cariogenic biofilm promotes further lesion progression. If lesion activity continues unchecked, it will lead to pulpal inflammation, pain and dental infection.

Why restore teeth?

Traditional restorative management involves carious tissue removal and reasons for this have historically included to:

1 withstand the packing of restorative materials and to help retain the restoration mechanically (for example, dental amalgam),

2 remove bacteria so stopping the caries process,

3 remove demineralised discoloured dentine.

However, thanks to research leading to a better understanding of the caries process and improved evidence from clinical studies, these reasons need updating, clarification and translation into clinical practice:

a. With the development of adhesive bioactive / bio-interactive restorative materials, removal of such large quantities of dental hard tissues is no longer justified.

b. Given the adverse effects that a good peripheral seal of the adhesive restorative material to prepared cavity walls have on the viability of remaining bacteria and their cariogenicity, carious tissue removal simply to remove bacteria in order to halt the caries process is neither logical nor justified [9-12]. In a similar fashion, neither is disinfecting the cavity prior to restoring, in order to kill all remaining bacteria.

c. Demineralised, but structurally intact dentine that can be remineralised should be preserved [13-15]. However, clinical discrimination between these layers of infected and affected dentine is difficult.

Carious lesions will arrest if the biofilm is regularly disturbed, “any lesion at any stage of its progression can arrest” [8] (Figure 1). However, there are circumstances where this is not possible and these are related to patient behavioural factors or where it is desirable to restore lost structure, integrity, form and/or aesthetics. The contemporary aims of operative restorative management have now evolved to:

1. aid biofilm control on a restored, rather than from a cavitated, tooth surface and thereby manage caries activity at this specific location;

2. protect the pulp-dentine complex and arrest the lesion activity by sealing the coronal part with an adhesive dental material;

3. restore the function, form and aesthetics of the tooth.

In conclusion, the only evidence-based reason for selective carious tissue removal is to create a sufficiently large cavity volume and surface area to provide restoration bulk and bond to, whilst maintaining adequate tooth structure to support the restoration, so as to optimize tooth-restoration complex longevity.

What are the guiding principles for removal of carious tissue?

Carious tissues should only be removed when there is no feasible alternative management such as cleaning cavities regularly with brush and fluoride toothpaste, a method particularly suitable in primary teeth. The guiding principles behind that process of removal are to:

1. preserve non-demineralised and remineralisable tissue,
2. achieve an adequate peripheral seal by placing the restoration material onto sound dentine and/or enamel where achievable,
3. avoid discomfort/pain and dental anxiety. Use methods that have a proven track record of initiating no or low levels of anxiety and pain, such as Atraumatic Restorative Treatment (ART), Hall technique on primary dentition, chemomechanical agents (e.g. Carisolv™ gel (Rubicon Lifesciences, Sweden)) etc.
4. maintain pulp health by avoiding dentine excavation close to the pulp so minimising the risk of pulp exposure, i.e. leave softer affected dentine in close proximity to the pulp if required. Avoiding pulp exposure significantly improves the lifetime prognosis of the tooth and reduces long-term management costs [16-18].
5. maximise longevity of the tooth-restoration complex by removing enough soft dentine to place a durable restoration of sufficient bulk and resilience, whilst maintaining sufficient surrounding tooth support for the restoration.

When dealing with permanent teeth with sensible (vital) pulps free from pathologic signs and symptoms, these last two aims, maintaining pulp health and maximising tooth-restoration complex longevity, should be balanced against each other. In deep carious dentine lesions (radiographically involving the inner (pulpal) third or quarter of dentine, or with a clinically assessed risk of pulp exposure), preservation of pulp health should be prioritised (Figure 2A). In shallow or moderately deep carious lesions (those not reaching the inner third or quarter of the dentine), maintenance of tooth-restoration complex longevity might have more significance (Figure 2B).

How should different carious lesions be managed?

The decision process as to which management strategy to use should follow a rational justifiable pathway (as described here), with the single most important question being, “When does one need to intervene operatively (invasively)?”

The recommended minimally invasive operative interventions described here are for:

- primary and permanent teeth (distinctions are discussed where relevant);
- teeth that are pain-free (or presenting with reversible pulpitis only);
- teeth with an active carious lesion extending into dentine
- where there is no irreversible pulp pathology detected

Non-cavitated carious lesions

Non-cavitated (i.e. cleansable) incipient lesions can be managed non-operatively using biofilm disruption / removal (regular toothbrushing using fluoridated toothpaste)[19] coupled with adjunctive topical remineralisation therapies where necessary (targeted at high caries risk individuals), or by therapeutic fissure sealing over the early lesion, predominantly carried out for occlusal pits and fissures [20] (Figure 3).

Non-cavitated but radiographically extensive carious lesion

Occlusal lesions that appear clinically non-cavitated but radiographically extend significantly into dentine might not arrest through biofilm control alone. Such lesions can be therapeutically fissure sealed but the integrity of the sealant must be monitored and consideration given to the possibility of a 'trampoline' effect from the underlying softer infected, completely demineralised dentine leading to mechanical failure of the sealant. If that happens the tooth eventually will also require further invasive restoration. The positive evidence for therapeutic fissure sealants is increasing [21,22].

Cavitated carious lesions

Cavitated dentine lesions that are accessible to visual-tactile and activity evaluation are potentially cleansable lesions (i.e. lesions that are assessed as being cleansable by the motivated patient). These can be made inactive, i.e. not requiring further operative treatment as their progression is unlikely and as such, can be managed non-operatively (non-invasively), i.e. via biofilm removal through oral hygiene procedures and fluoridated toothpaste or remineralisation therapies. Lesions that are not cleansable are likely to be pathologically active and progress, but might be made into cleansable lesions ('Non-Restorative Cavity Control'). This type of cavity modification appears applicable for use in primary teeth and was advocated by GV Black in 1908. Currently, more evidence is required for guiding the practitioner, particularly related to the age when the Non-Restorative Cavity Control can start. This includes additional supporting control measures such as application of fluoride varnish, remineralising agents or placing a layer of high-viscosity glass-ionomer over the floor of the cavity. Lesions with surface cavitation that cannot be managed by making them cleansable should be considered non-cleansable and therefore, active. These lesions usually need further operative interventions for their management (Figure 4).

Clinical presentation of carious dentine

Given the available clinical and microbiological evidence, the level and extent of carious tissue removal can be centred around levels of hardness of the remaining dentine [3,23]. These subjective hardness levels include the descriptors soft, leathery, firm and hard. For practical purposes, assessing the force required for a sharp dental explorer to make a mark on carious tooth tissue is currently the most practical way for the clinician to assess its degree of "softness" or "hardness". Some practical guidance is offered below to describe the physical properties that are associated with different histological states of dentine. It should be remembered that these states are only part of a continuous spectrum of presentation of carious dentine and do not exist in discrete zones or layers (Figure 5).

Soft dentine

Soft dentine deforms when a dental explorer (sharp probe) is pressed onto it, with a latent "stickiness". It can be easily scooped up (e.g. with a sharp hand excavator) with little force being applied. This dentine consistency is often described as caries-infected dentine and can appear moist in consistency.

Leathery dentine

Leathery dentine does not deform when an instrument is pressed onto it. Without much force, it can still easily lifted – a latent "tackiness" can be elicited. There may be little difference between leathery and firm dentine with leathery being a transition on the spectrum between soft and firm dentine. This dentine consistency is often described as caries-affected dentine.

Firm dentine

Firm dentine is physically resistant to hand excavation requiring some pressure to be exerted through an instrument to lift it.

Hard dentine

A pushing force needs to be used with a dental explorer instrument to engage the dentine and only a sharp cutting edge or a bur will lift it. A scratchy sound or 'cri dentinaire' can be heard when a straight probe is taken across the dentine. This consistency classically signifies sound dentine.

How should carious tissue be removed in teeth with sensible, asymptomatic pulps?

Previous terms for removal of carious tissues described the outcome of the excavation process and were problematic. The criteria that demarcate the extent to which carious tissues are removed have not been defined or agreed. These might include tissues being free from bacteria, demineralised dentine, discoloured dentine or even "soft dentine". Furthermore, there are no commonly used and easily accessible technologies available to reliably assess any of these rather subjective endpoint criteria in a clinical setting. Lastly, if more advanced techniques are available in the future that can, for example, measure bacterial load or mineral loss, it is most likely that areas of dentine will be found where there is incompletely removed carious tissue seen after previously attempted complete removal and vice versa. In other words, when to stop removing carious tissue is arbitrary and dependent upon the operator's understanding of the caries process in the individual tooth and patient that is being treated.

Thus, it seems logical to use procedural definitions to describe exactly what has been *done* instead of measuring what was attempted to *achieve*. Using this rationale, the term "selective removal" is preferred. In selective removal, different excavation criteria are used when assessing the periphery of the cavity as opposed to the area in close proximity to the pulp. The periphery of the cavity should ideally be surrounded by 'sound' enamel to allow the optimal adhesive seal. The peripheral dentine should ideally be hard – with similar tactile characteristics to sound dentine, such as a scratching noise when scraping the surface with a sharp hand excavator or dental probe. However, firm / leathery carious tissue should

be left towards the pulpal aspect of the cavity, with only enough of it removed to allow a durable bulk of restoration to be placed, whilst avoiding pulp exposure at all costs. Following this rationale, five main strategies for removing carious dentine, based on the hardness of the dentine are proposed. Decisions regarding the use of these strategies are guided by the lesion depth and activity (Figure 6).

Non-Selective Removal to Hard Dentine (formerly known as complete excavation or complete caries removal) uses the same criterion to assess the endpoint of carious tissue removal for all parts of the cavity, i.e. peripherally and pulpally. Only hard sound dentine remains so that demineralised dentine, 'free' of bacteria is 'completely' removed. *This unnecessarily aggressive traditional operative approach is considered gross over-treatment and no longer advocated.*

Selective Removal to Firm Dentine leaves 'leathery' dentine pulpally; there is a feeling of resistance to a hand excavator whilst the cavity margins and peripheral dentine are left hard (scratchy) after excavation is complete. *"Selective Removal to Firm Dentine" is the treatment of choice for both dentitions, in shallow or moderately deep cavitated dentine lesions (i.e. lesions radiographically extending less than the pulpal third or quarter of dentine). In deeper lesions, "Selective Removal to Firm Dentine" puts the pulp at risk of "physiological stress" or exposure, which is why other strategies should be considered in these cases.*

Selective Removal to Soft Dentine is recommended in deep cavitated lesions (i.e. extending into pulpal third or quarter of the dentine). Soft carious tissue is left over the pulp to avoid exposure and "stress" to the pulp, encouraging pulp health, whilst peripheral enamel and dentine are prepared to hard dentine, to allow an adhesive seal to be achieved by placement of a durable restoration. "*Selective Removal to Soft Dentine" reduces the risk of pulp exposure in deep lesions significantly compared with "Non-Selective Removal to Hard Dentine" or "Selective Removal to Firm Dentine".*

Stepwise Removal is carious tissue removal in two stages / visits [12,24,25]. Soft carious tissue is left only over the pulp in the first visit and peripheral dentine is prepared to hard dentine, to allow a complete and durable seal of the lesion. A provisional restoration, sufficiently durable to last up to 12 months is placed (e.g. high-viscosity glass ionomer cement). After this time, the restoration is removed and the previously retained carious dentine is further removed until firm dentine is reached, formed during the restoration period as the caries process arrests. There is clinical evidence that the second removal stage may be omitted as this increases risk of pulp exposure [3,26,27]. The second visit also adds additional cost, time and potential discomfort to the patient. In the primary dentition, teeth have a limited lifespan so Stepwise Removal is not considered necessary for primary teeth and "Selective Removal to Soft Dentine" should be carried out.

How should carious tissue removal be carried out?

There are several methods and different technologies for clinical carious tissue removal, including excavation with hand instruments, tungsten carbide / ceramic / carbon-steel / polymer burs, air-abrasion, sono-abrasion, chemo-mechanical agents, and lasers. Studies on clinical advantages and disadvantages of the different excavation methods indicates some evidence finding hand or chemo-mechanical excavation potentially advantageous towards selective removal [28-31]. These technologies

may also reduce pain and discomfort during treatment in comparison to the other methods mentioned above [32], although further evidence is required.

Examples of specific caries management protocols

Atraumatic Restorative Treatment (ART)

ART uses hand instruments for opening small cavities and for removing carious tissue. The cavity is sealed with an adhesive restorative, usually a high-viscosity glass ionomer cement that simultaneously is used to seal any available remaining pits and fissures. In small and medium dentine cavities, ART follows the "Selective Removal to Firm Dentine" protocol whilst in deep lesions the "Selective Removal to Soft Dentine" is followed [33].

Hall Technique

The Hall Technique is a method for sealing carious lesions in primary molar teeth using preformed metal crowns. The correct size of crown is chosen to fit the tooth, filled with glass ionomer luting cement and seated firmly over the tooth. This avoids the need for tooth tissue removal and local anaesthetic and in two randomised control trials children preferred the technique to conventional restorations [34,35] and results indicated that this technique outperformed conventional restorations [36,37]. The technique compares favourably with conventional crowns [38]. Appropriate lesions and how to carry out the technique are explained at { HYPERLINK "https://en.wikipedia.org/wiki/Hall_Technique" }.

How should the resulting cavity be managed?

Traditionally, cavity disinfection and cavity lining procedures have been advocated after removing carious tissue, prior to restoring the cavity definitively. Cavity disinfection has been advocated to reduce the number of remaining bacteria. However, given that the presence and number of bacteria are of limited importance in continued caries progression and the development of **c**aries **a**ssociated with **r**estorations and **s**ealants (CARS, also known as secondary or recurrent caries), the necessity for cavity disinfection is now questionable**.** Studies have shown no difference in restoration survival rate after disinfecting cavities compared to no cavity disinfection **[39].** Cavity disinfection procedures do increase treatment time and cost.

Cavity lining (most commonly accomplished with calcium hydroxide or its derivatives) has been used traditionally when treating deep carious lesions in an attempt to keep the pulp-dentine complex viable and functioning through reducing the number of residual viable bacteria, remineralising dentine, inducing reactionary dentine, isolating the pulp and protecting pulp cells from noxious stimuli [40]. Again, the antibacterial effects are of limited relevance [41,42]. Remineralisation of remaining demineralised dentine seems to be mediated by pulp cell activity and may not be aided by separate liners [43]. Although certain liners seem capable of inducing tertiary dentine production and reducing pulpal inflammation [44], the evidence is sparse and the clinical relevance unclear [27,45,46]. The isolation of the pulp against thermal insult is relevant when placing thermally conductive restorative materials (i.e. dental amalgam). Isolating

the pulp when placing resin-based restorations might be beneficial as monomers may penetrate through dentine into the pulp [47,48]. In summary, placement of separate cavity lining materials are not necessary to control pathological progression within the sealed lesion, but might help impede monomer penetration and avoidance of fracture of the remaining dentine when resin composite is the restorative material. More clinical evidence is required for the latter.

How should the cavity be restored?

The choice of materials for restoring cavities should be guided by the location and extent of the lesion, the caries risk, lesion activity and specific patient conditions and environment. There is no definitive evidence to support particular materials for restoring teeth after selective carious tissue removal to soft or firm dentine.

What should be done to make these suggested changes work

It takes a long time to change clinical practice in medicine and dentistry. It is acknowledged how difficult it can be to change patients' behaviour / lifestyle and it is no different in trying to change the professions' own attitudes. Contemporary knowledge is necessary for this change to take place but alone, this is not sufficient. Minimally invasive clinical skill sets, for detection, diagnosis and operative techniques need to be mastered as well as nurturing the right attitude for evidence-based change to deliver the best oral healthcare for patients. An important starting point for such change are dental training institutions globally. Cariologists and particularly faculty-based instructors at the skill laboratories and those employed in the clinic should be trained in-house in contemporary Cariology and cavity treatments that furnish them with the knowledge to then educate dental students [4].

Summary recommendations

1. Preventing carious lesions means managing the disease, the caries process, with inputs from both the oral healthcare team and the patient. For existing lesions, dentists, alongside and leading their oral healthcare teams, should work with the patient to manage oral health and as a consequence to control disease activity. In doing so, dental hard tissues are preserved, initiation of the destructive restorative cycle is avoided and the tooth retained in clinical function for as long as possible. Further recommendations for managing non-cavitated lesions are beyond the remit of this paper.
2. When carious lesions are non-cleansable by the patient and sealing is no longer an option, minimally invasive operative restorative interventions are indicated.
3. Restorations are placed in cavitated lesions to help the patient in plaque biofilm control, to protect the dentine-pulp complex and restore the function, form and aesthetics of the tooth. Carious tissue removal aims to create conditions for a long lasting tooth-restoration complex, preserving healthy and remineralisable tissue, achieving a sufficient physical seal and

maintaining pulp health. It is accomplished preferably with methods that minimise dental anxiety and pain/discomfort for the patient.

4. In deeper lesions in teeth with sensible (vital) pulps, preserving pulp health should be prioritised over "mechanical" restoration success, whilst in shallow or moderately deep lesions, restoration longevity might be considered the more important factor.
5. For teeth with shallow or moderately deep lesions, "Selective Removal to Firm Dentine" excavation protocols should be followed.
6. In deep lesions (radiographically extending into pulpal third or quarter of the dentine) in primary and permanent teeth, "Selective Removal to Soft Dentine" should be performed.
7. In permanent teeth, Stepwise Removal might also be an option for deep lesions (with the understanding that the second stage visit may not be necessary).
8. Hardness of the dentine should be the primary criterion for assessing, describing and reporting on carious tissue and its removal. There is insufficient published evidence to recommend one method for carious tissue removal over another. Variations will always occur due to the different MI operative skill sets practiced by dentists the world over.
9. Cavity disinfection currently has no significant evidence-base for its inclusion in routine operative caries management protocols.
10. Recommendations for restoring teeth with particular restorative materials after using different carious tissue excavation protocols cannot be made at present.

Notes

The following are members of the ICCC (International Caries Consensus Collaboration: Falk Schwendicke (Germany), Jo E. Frencken (Netherlands), Nicola Innes (UK), Avijit Banerjee (UK), Lars Bjørndal (Denmark), Wolfgang Buchalla (Germany), Marisa Maltz (Brazil), David J. Manton (Australia), David Ricketts (UK), Kirsten Van Landuyt (UK), Guglielmo Campus (Italy), Sophie Doméjean (France), Margherita Fontana (USA), Soraya Leal (Brazil), Edward Lo (China), Vita Machiulskiene (Lithuania), Andreas Schulte (Germany), Christian Splieth (Germany), Andrea Ferreira Zandona (USA).

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Figures and legends

Figure 1: An arrested and remineralised carious lesion on the buccal surface of a lower first permanent molar. The lesion was active (detectable by being rough when a ball ended probe is dragged across the surface) whilst the tooth was erupting and the area was caries prone by being sheltered by the gingivae but is now inactive (smooth when a ball ended probe is dragged across the surface). The patient's oral hygiene habits improved and the area around the gingivae has not undergone demineralisation indicating that during the last stages of eruption the biofilm was removed and cleaning has continued. The lesion shape follows the shape of the gingiva and the white area can be thought of as a scar from previous disease. Note this is an example of an incipient lesion that has not taken up dietary stains to form the arrested "brown spot lesion".

A

B

Figure 2. A) Radiograph of a maxillary left first permanent molar with a deep carious lesion extending to the inner (pulpal) 1/3 of dentine where preservation of pulp health should be prioritised during operative intervention and B) a shallow carious lesion in the mandibular left second molar (confined to the inner third of the dentine) where the tooth-restoration complex longevity might have more significance when deciding on the minimally invasive operative management options.

A)

B)

Figure 3. Radiograph showing therapeutic fissure sealants over occlusal surface carious lesions in primary molars. A) radiograph taken when the child was 5 years old showing initial carious lesions in all four right first primary molars. These were fissure sealed and radiograph B) was taken 2 years later. There is no clinical or radiographic evidence of progression of any of the lesions. The fissure sealants were repaired as necessary in order to maintain the seal.

Figure 4. A maxillary first permanent molar with a carious lesion showing surface cavitation. This has created a sheltered microniche that will support a cariogenic biofilm to thrive. The lesion is considered clinically non-cleansable from examination and therefore, active. These lesions usually need operative intervention.

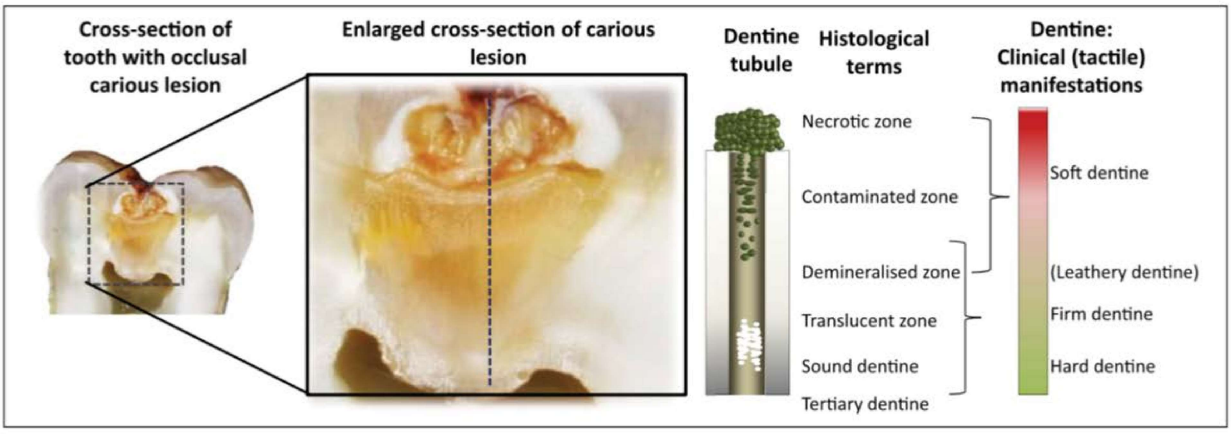

Figure 5. Diagrammatic representation of the carious cavitated lesion (after Ogawa et al., 1983) [13]

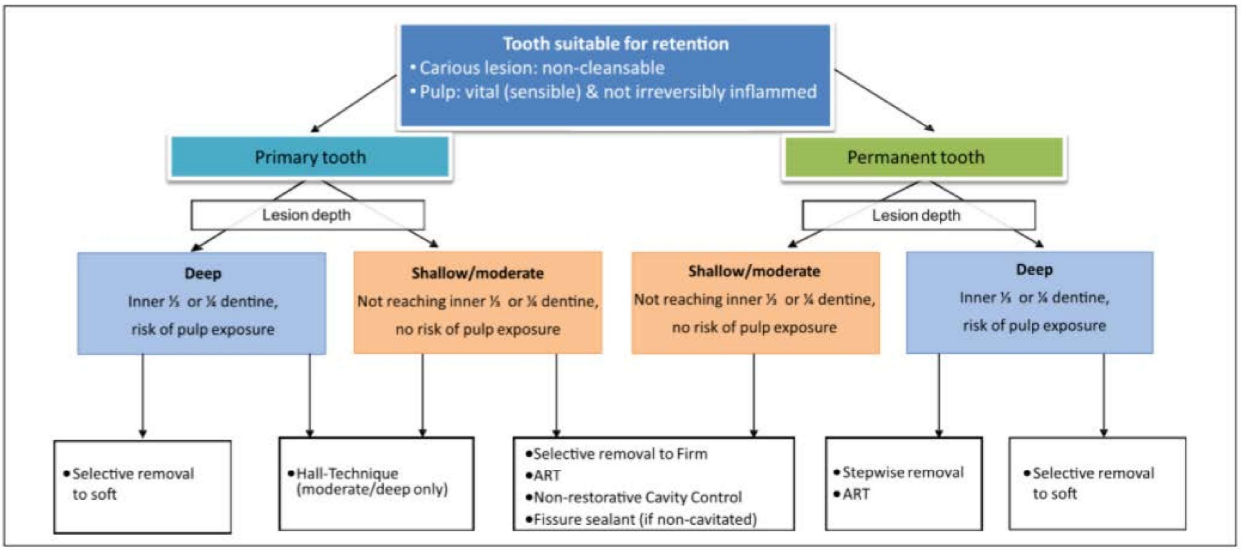

Figure 6. Decision-making flowchart for the minimally invasive operative management non-cleansable carious lesions in retainable teeth with vital pulps [7].

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